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INTERIM REPORT

ON

COPPER VAPOR LASER SCALE DEMONSTRATION

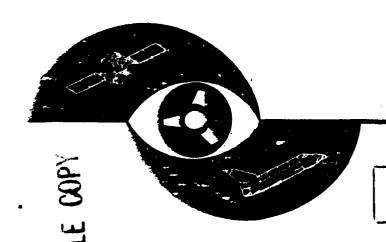|	
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I. INTRODUCTION

The principal purpose of this program is the demonstration that copper vapor lasers can be scaled to large volumes and pulse energies. A 4" ID laser with a projected capability of over 0.25 J per pulse was to be built and tested and a computer simulation model developed. The specific output goal was 25 microjoules per cm^3 of active volume.

II. EXPERIMENT

A. Subscale Model

Several different versions of a 1" ID copper laser were built to test design approaches to be used on the large diameter device. The following lists the most important findings.

1) Investigated techniques for choosing and outgassing laser materials.

2) Demonstrated that molecular contaminants can be reduced so that electric field strengths proposed for the large device (>200 V/cm) will not produce discharge constriction.

3) Demonstrated that a glow discharge heating technique can be used to heat the laser to appropriate temperatures (>1400°C).

4) Investigated several mechanical and electrical designs for ruggedness and reliability.

5) Tested burst mode operation of an electrical discharge. The thyratron (EG&G HY5312) had been tested on another program to 50 kV.

6) Demonstrated lasing.

B. Full Scale Device

A 4" ID device was designed based upon the results obtained with the subscale model. These designs were then incorporated into detailed drawings* and the device was built.

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*Done on another program.

The hot zone length is about 43" (109 cm) with a capability of extension
to 59" (150 cm). The outer diameter is 9" and its total length is 8'11". It
has been designed as a flexible research facility and so has the capability
for easily changing storage capacitance and circuit inductance over a wide
range. Laser tubes up to 5-6" ID can be used though the configuration currently
fits a 4" ID tube.

Vacuum, thermal and mechanical troubleshooting have been completed. Glow
discharge power sufficient to heat the laser to operating temperatures has also
been successfully applied. Pulsed discharge tests have also been successfully
conducted.

Laser outgassing is now underway.

III. COMPUTER MODEL

A. Modifications

A copper vapor laser computer simulation model previously in operation
(CULSODE) was modified for use on this program.

The original CULSODE discharge circuit has been replaced with a more
realistic one. This circuit includes not only the peaking capacitor and parallel
leakage resistor but also the unavoidable parasitic inductances. Furthermore,
the thyratron switching function was changed from the original relatively simple
two-step voltage function to a three-stage function which includes a time
dependent, switch closing resistance and a slow switch opening effect to simulate
circuit recharge.

This circuit is solved by the current loop method. The current loop together
with all the original chemical and radiative equations iterate to a final solu-
tion at each point in time before proceeding to the next time interval. The
modified code is called CUHE 1.

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Another major change has involved changing the buffer gas constants (atomic energy levels, rate constants, radiative lifetimes, atomic weights, diffusion coefficients) to those of neon. This code is called CUNE 1.

Other changes to both these codes include:

a) The calculation of thermal transfer (gas heat loss to the walls) has been expanded so as to make it a function only of the buffer gas and other fundamental inputs. This replaces the previous simpler but semi-empirical heat transfer function and transfer input constant.

b) An option has been added to the program to permit automatic insurance of chemical balance/thermal balance for the first iteration's set of species. These initial species concentrations are internally calculated from pressure, gas and wall temperatures, and electron density.

c) A convenient plot routine has been added to allow rapid scanning and to provide hard copies of the results of selected output parameters.

d) The printout has been modified to include more input information, as well as some additional electrical and plasma characteristics in the output.

e) The code has been modified to change species concentration with changing gas temperature when proceeding from one laser pulse to the next.

f) Multiple cases, i.e. different input parameters, can now be set up in advance with far more case-to-case parameter variation than in CULSODE.

The CUNE 1 code has been validated against experiments conducted with a 6 cm laser. Agreement has been good, simulated average power differing from experiment by about 10%.

B. <u>Simulations</u>

A large number of simulations of the 4" ID laser were run using CUNE 1 so as to determine optimum operating conditions. It was found that high voltage

low storage capacitance operation produced the highest efficiency and output. An output of 0.45 J at 1.3% efficiency was simulated for 60 kV voltage on a 19 nF capacitor. Higher efficiency (1.9%) but lower pulse energy (0.34 J) were obtained with lower capacitance.

An insight has also been gained into the importance of the number of electrons remaining after each discharge as preionization for the next. When the number is too high, as at high repetition rates (e.g. 5 kHz) in copper, the voltage drop across the laser is limited by its high conductivity. It is consequently difficult to develop the high field strengths and the high electron temperatures needed for proper coupling to the excitation function of the upper laser state. However, low repetition rate, as contemplated for these tests, provides sufficient time for recombination to proceed. Mean electron temperatures of over 12 eV have been obtained in the simulations just discussed. This is well above values obtained with high repetition rate operation.

IV. SUMMARY

A computer model for simulation of the copper laser has been constructed and validated against 6 cm laser experiment results. Simulation of 4" laser operation predicts output of 0.45 J at 1.3% efficiency.

A subscale model copper laser was built to test out design concepts for the 4" ID laser. After successful tests with this device, the 4" device was designed and built. It has undergone preliminary troubleshooting and is now being outgassed.

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